Algal Blooms In Wisconsin

The Challenges of Phosphorus Reduction, Invasive Species, and Climate Change

BY GINA D. LALIBERTE

Unsightly multi-colored algal blooms appeared earlier than usual on lakes across Wisconsin in the summer of 2012. Their premature arrival was induced in part by an exceptionally warm period in March when temperature records were set throughout the state.

The unseasonably warm weather changed the trajectories of many natural communities. Door County's cherry trees budded early, only to lose their blossoms during April's hard freezes. Southerly winds associated with the warm spell brought migrating birds into the state, some at record early dates. In lakes throughout Wisconsin, the clock was springing forward for algal communities awaiting the start of the growing season, allowing them to take up nutrients and explode into growth earlier than usual.

Why algal blooms are a concern

Found in every aquatic system in Wisconsin, algae are important members of the food webs of our lakes and rivers. Using photosynthesis, algae make carbohydrates and oxygen from carbon dioxide and water. Algae (and their carbohydrates) are eaten by zooplankton, insects, snails, and the many other organisms that serve as the base of all aquatic food webs. We can also thank algae for the air we breathe today, which contains oxygen produced in part by algae. Algae require the nutrients phosphorus and nitrogen for growth, but when these nutrients are available in excess of their needs, populations can rapidly increase to nuisance levels in an *algal bloom*.

We all know that algal blooms are unsightly and foul-smelling, but what isn't immediately apparent is the damage that excessive or nuisance growths of algae can cause to our lakes and rivers. Algal blooms indicate an imbalance of excess nutrients, primarily phosphorus, in aquatic systems. Blooms in Wisconsin lakes and rivers usually consist of green algae or blue-green algae known as *cyano-*

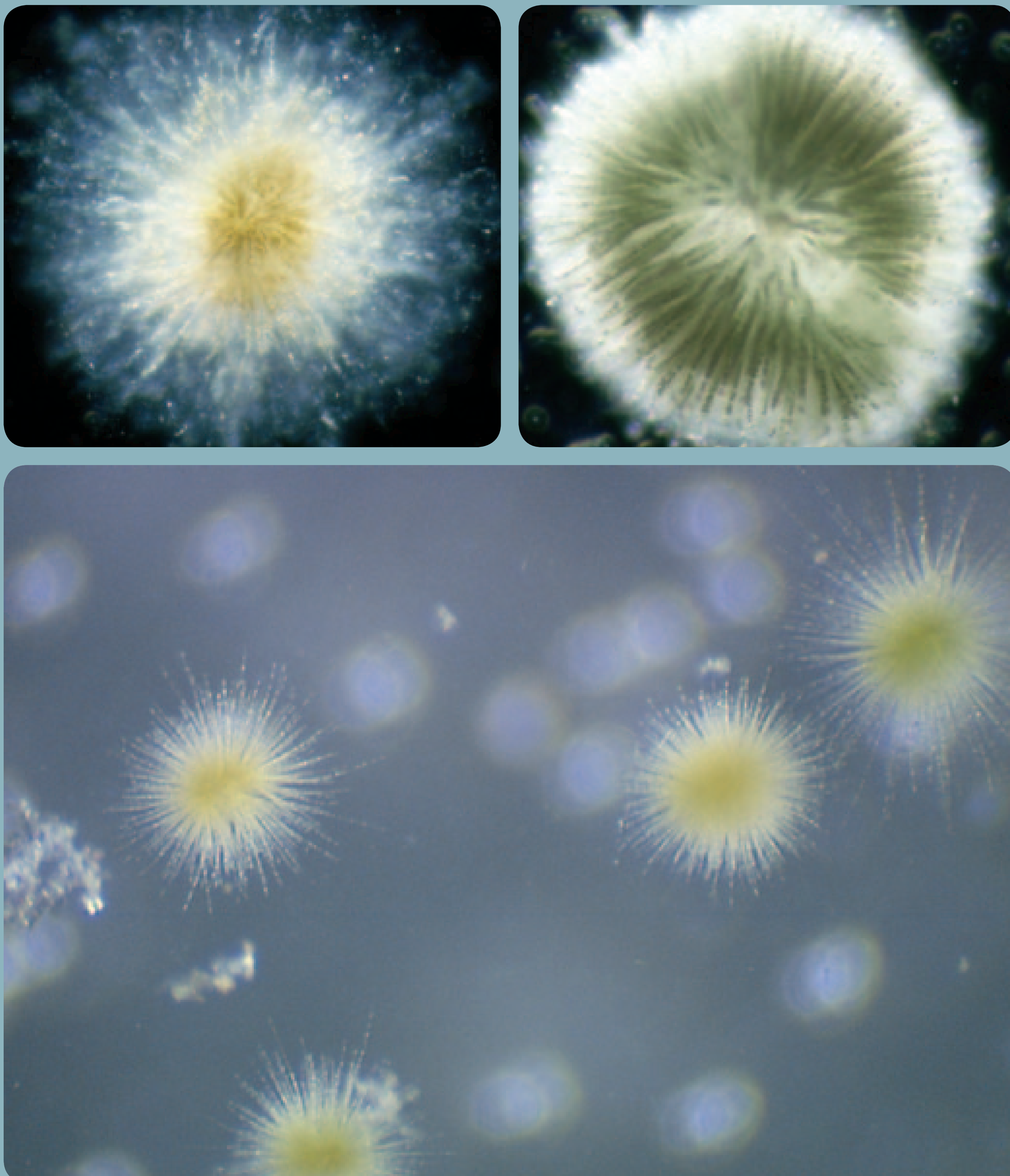

Photo credits: Gina D. LaLiberte/Wisconsin Department of Natural Resources

Above: ***Gloeotrichia echinulata*** **colonies look like pale green to light olive-green pinhead-sized spheres in the water**

bacteria. Ecologically, an algal bloom may cause the dissolved oxygen levels around the bloom to plummet when it decays, adversely affecting surrounding aquatic life and raising the potential for fish kills. Moreover, blooms of filamentous green algae may bind together beds of aquatic plants, thereby shading the plants from the sun and inhibiting growth. If thick enough, these filamentous blooms can even entrap invertebrates and small fish.

While green algal blooms and cyanobacterial blooms can have detrimental effects on the composition and function of aquatic food webs, the latter pose additional dangers to both people and aquatic organisms. Irritants called *lipopolysaccharide compounds* are found in the cell walls of all cyanobacteria. These compounds may cause rashes, gastroenteritis, or respiratory symptoms from recreational exposure.

Some cyanobacterial species have the capability to produce *neurotoxins*, *hepatotoxins*, or *cytotoxins* that can damage the nervous system or organs of living creatures, causing illness or even death if enough are ingested. Animals are at the highest risk for death from ingesting cyanobacteria, because they do not hesitate to drink scummy water or lick their fur after swimming in cyanobacterial blooms. *Jf`ol`vpqfkp* are the most common algal toxins in Wisconsin's waters. They may bioaccumulate in aquatic organisms and have been linked to increased rates of liver cancer in human populations when people drink and cook with untreated surface waters containing cyanobacteria.

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The causes of blooms

If we want to minimize algal blooms in our lakes and streams, the first place we need to do some work isn't in our waters—it's on our land. Human activities on land deliver the nutrients phosphorus and nitrogen to lakes and rivers and thus are the primary drivers of algal blooms. Invasive species and climate change can also play a role in their expansion.

While algal blooms may be increasing in both size and frequency, they are certainly not a new phenomenon in Wisconsin. In an 1889 edition of *Transactions*, the scientific journal of the Wisconsin Academy, botanist William Trelease noted the occurrence of cyanobacterial blooms on Lakes Mendota and Monona:

> Every season a greenish-yellow scum occurs in greater or less quantity on Third and Fourth Lakes [Mendota and Monona], during the hot weather of summer, after the water has been calm for a number of days in succession.

Of course, wastewater management practices in 1889 were vastly different from those followed today; nutrient-laden sewage and effluents from leatherworks, cheese factories, and other industrial plants were discharged directly to the lakes. Such discharges are now regulated.

But as Wisconsin's population and development have increased, the amount of nutrients flowing into our rivers and lakes from point sources and non-point sources has grown as well. A point source is wastewater from a single source, such as a wastewater treatment facility or a factory, discharged to a waterway. Non-point sources, in contrast, come from many sources and consist of runoff flowing over urban, agricultural, or forested lands, bringing sediments and nutrients into streams and rivers.

In considering non-point sources, it's important to remember that we've lost nearly half of our state's wetlands to drainage and development since the 1800s. Lake- and river-associated wetlands help to remove nutrient-laden sediment from runoff as it approaches a water body. Without wetlands to filter the runoff, more nutrients are deposited in our lakes and rivers.

The trouble with phosphorus

Like other plant life, algae need the nutrients nitrogen and phosphorus for growth. In Wisconsin's waters, growth of aquatic plants and algae is limited by the amount of available phosphorus. Even small increases of phosphorus in lakes and rivers, whether from point sources or non-point runoff, can fuel extensive growth of aquatic plants and algae. In order to keep excess phosphorus from entering our rivers and lakes, the State of Wisconsin has recently set numerical criteria limiting the amount of phosphorus that may enter our waterways via industrial and municipal point sources, and has also taken steps to address non-point sources from agricultural lands, storm water, and construction sites via a variety of performance standards, adaptive management, and water quality trading strategies.

Keeping excess phosphorus out of our lakes and rivers is key: once phosphorus enters a system, it is extremely difficult to remove it. Even if phosphorus inputs to a lake are halted, the nutrients stored in lake sediment can continue to cause algal blooms for many years.

Sediment-bound phosphorus can be converted to a form easily taken up by plants and algae if lake sediments become *anoxic* (depleted of dissolved oxygen). This process, called *internal loading*, occurs if lake water is strongly stratified by temperature. Microorganisms deplete oxygen from the deepest, coldest water layers through respiration, and in the absence of mixing with shallower, warmer, oxygenated water, phosphorus is released from sediments. This pool of internally loaded phosphorus is dispersed into the water column during fall or spring turnover when the entire water column mixes. It can also be used by cyanobacteria while the lake is still stratified, as some cyanobacterial species regulate their buoyancy to move deep into the lake, take up phosphorus, and then rise back to the lake surface, where they can form a bloom.

Physical characteristics of lakes and rivers also play a role in nutrient dynamics. Phosphorus-rich sediments

Photo credit: Neil Trombly/Wisconsin Department of Natural Resources

Above: Cyanobacteria blooms spread across Cedar Lake in Polk County. Vivid colors appear in cyanobacterial blooms like these as cell decomposition begins, releasing pigments into the water

in shallow lakes and rivers are easily disturbed by human activity and wind, which mix sediment nutrients into the water column. These nutrients fuel algal blooms and plant growth. Watershed size, lake volume, and *flushing rate* (the rate at which water flows through a lake) also affect the likelihood of algal bloom formation. Larger watersheds contribute more nutrients to lakes from runoff. Greater lake volumes may dilute the effects of more runoff, but lower flushing rates allow sediments and nutrients to settle into lakes instead of being washed downstream. Lakes lacking outlets are particularly susceptible to nutrient enrichment, as any excess nutrients entering from the watershed remain there.

Another complication to the relationship between nutrients and algal blooms is the way in which cyanobacteria adapt physiologically and thus are free from some of the nutrient limitations of other algae groups. Cyanobacteria have the advantage of being able to take up and store phosphorus when it is abundant, a process called *luxury consumption*, and use it later to fuel bloom growth when phosphorus levels diminish in the water column. In addition, some species of cyanobacteria are capable of nitrogen fixation, a process by which atmospheric nitrogen is "fixed" or converted to ammonia, which cyanobacteria need for growth. In this way the bacteria can easily maximize cell division rates, even if available nitrogen levels are low in an aquatic system. Both of these adaptations give cyanobacteria an advantage over other algal groups that must have readily available nutrients in the water column for their growth.

Invasive species make it worse

Invasive species like carp, zebra mussels, and quagga mussels can play a role in promoting algal blooms in our waterways, sometimes even if nutrients are present at moderate to low levels. Both carp and dreissenid mussels like the zebra and quagga can alter a lake habitat from one that supports balanced aquatic life to one that fosters excess algal growth.

Carp are notorious for feeding on and uprooting the aquatic plants that normally compete with algae for nutrients. This lake-bottom feeding mixes sediments into the water column; the sediments, in turn, shade aquatic plants and thereby inhibit their growth. With fewer aquatic plants, more sediment nutrients enter the water column, causing a shift to an algae-dominated system. Removing carp from lakes has been shown to improve water clarity and reduce algal blooms. For example, about half of the carp population of Madison's Lake Wingra was removed over the course of two years through a project led by now-retired Department of Natural Resources limnologist Dick Lathrop. With reduced competition, the remaining carp stirred up less sediment when searching for food. As water clarity and quality improved, more aquatic plants were able to grow and fewer algal blooms occurred.

Invasive zebra mussels and quagga mussels also contribute to the development of nuisance blooms of filamentous green algae and cyanobacteria. Once these dreissenid mussels hit peak population density, they are incredibly efficient at removing phytoplankton from the water column through their filter feeding activity, which has significant ecological effects.

In Lake Michigan, the filter feeding of zebra and quagga mussels has increased water clarity, resulting in more areas of the lake bottom receiving enough sunlight for algal growth. The mussels also act to drive phosphorus cycling close to the bottom of the lake. They filter phytoplankton out of the water column for food and excrete both feces and rejected filtered particles. As the mussels' excreted waste breaks down, phosphorus is liberated and then taken up by the filamentous green *Cladophora* algae that grow on the mussels' shells.

By offering *Cladophora* a place to grow, clearing the water so the algae receive light, and providing phosphorus through the breakdown of their wastes, zebra and quagga mussels have fueled excessive growth of *Cladophora* in nearshore areas. Because *Cladophora* can be dislodged by waves, it washes up on the western Lake Michigan shoreline in large amounts. As mats of *Cladophora* break down on shore and in waters close to shore, they can harbor *E. coli* and other bacteria detrimental to recreational water quality, as well as create an unpleasant odor and an unsightly spectacle for beach users.

Zebra and quagga mussels can also affect cyanobacterial blooms and have done so on a large scale in parts of the Great Lakes, particularly western Lake Erie, where recreational water quality has been severely compromised by blooms of the cyanobacterium *Microcystis*. Dreissenid mussels promote *Microcystis* in a unique manner: by selectively rejecting the toxic cyanobacterium as they filter phytoplankton from the water column, the mussels remove the other algal competitors and increase the concentration of *Microcystis*. *Microcystis* can also regulate its buoyancy, floating up toward the water surface where it dominates other blooms. Bloom promotion by zebra mussels can occur in inland lakes as well, and research in Michigan has shown that mussel-induced *Microcystis* blooms may occur even in lakes with low to moderate levels of phosphorus.

Climate change impacts

Wisconsin's climate is changing. The Wisconsin Initiative on Climate Change Impacts (WICCI), a partnership between the Wisconsin Department of Natural Resources and the University of Wisconsin–Madison Nelson Institute for Environmental Studies, examined meteorological records from 1950 to 2006. WICCI found that Wisconsin's average annual temperature is increasing, the growing season is longer, and annual average precipitation is on the rise. These trends, if they continue, are conducive to the growth of algal blooms and will especially favor cyanobacterial blooms.

Higher air temperatures cause higher water temperatures, which lead to more cyanobacterial blooms. Cyanobacteria grow optimally in warm water, up to 85°F, the temperature at which the growth of other types of algae is inhibited. Moreover, warmer lake waters can lead to stronger stratification, which can result in anoxic waters at the lake bottom and enhanced internal phosphorus loading.

Longer growing seasons don't affect just our fruits and vegetables; they also lead to extended algal bloom seasons, especially in late summer and early autumn when warm water temperatures favor cyanobacteria. Their physiological adaptations—phosphorus storage and nitrogen fixation—allow cyanobacteria to bloom even if nutrients are tied up in other algae and plant biomass at the end of the growing season.

The increase in precipitation in Wisconsin during the 1950–2006 period, which WICCI documented, resulted from both heavy snowfall and heavy rain-

Photo credit: Gina LaLiberte/Wisconsin Department of Natural Resources

Left: *Microcystis*, shown here next to the tip of a pencil, is the most common bloom-forming cyanobacterial genus in Wisconsin. Colony shapes are spherical to irregularly lobed and perforated

fall. Because the ground can absorb only a limited amount of moisture, large amounts of snowmelt and rainfall alike increase nutrient-laden runoff into aquatic systems, thereby enhancing algal blooms fueled by higher temperatures and longer growing seasons.

The future of algal blooms in Wisconsin

At first glance, the ecological deck seems to be stacked against the reduction of algal blooms in Wisconsin waters. Cyanobacteria especially have adaptations that maximize their growth in response to many of the changes we have made in our environment. Yet the mitigation of blue-green algal blooms is essential if we are to improve recreational water quality and protect public health.

Multiple agencies in Wisconsin, including the Department of Natural Resources and the Department of Agriculture, Trade, and Consumer Protection, are working to address the root cause of algal blooms in myriad ways, particularly by setting limits on phosphorous pollution. But these regulations require the cooperative effort of all stakeholders and a rigorous adherence to performance standards, adaptive management strategies, and water quality trading agreements.

In addition to state regulatory initiatives, direct efforts to reduce phosphorus inputs by individual citizens will help to prevent future algal blooms and enhance the value of our waters for the fishing, tourism, and real estate industries (see below). Continuing efforts to restore wetlands, remove carp from lakes when practical, and stop the spread of invasive zebra and quagga mussels to inland lakes will also reduce algal bloom occurrence and increase water quality.

These tactics to reduce phosphorus inputs and improve water quality through the enhanced ecological function of our lakes and rivers may be central to helping us to mitigate and adapt to the challenges of climate change. The unseasonably warm spring of 2012 may be an anomaly. Even if it is, the implementation of these phosphorus reduction strategies will help us to avoid a possible algal bloom-filled future in which the anomalous becomes the norm. ✺

CONNECT: What Can I Do?

Blue-green algae, also known as *Cyanobacteria*, are a group of photosynthetic bacteria that grow in lakes, ponds, and slow-moving streams when the water is warm and enriched with nutrients like phosphorus or nitrogen. Blue-green algae are most often blue-green in color but can also be blue, green, reddish-purple, or brown.

When environmental conditions are just right— generally between mid-June and late September—blue-green algae can grow very quickly. Many species are buoyant and will float to the surface, where they form scum layers or floating mats called *blooms.*

There are no quick or easy remedies for the control of blue-green algae once they appear in a lake or pond. Reducing the amount of nutrients that wash into our lakes and ponds will eventually reduce the frequency and intensity of blue-green algae blooms, but it may take a long time and a lot of community involvement to effectively change the nutrient concentrations in a water body.

Do not use an herbicide or algaecide to treat surface water that is experiencing a blue-green algae bloom. While it may kill the blue-green algae, any toxin(s) contained in the cells will be released at once, resulting in a slug of toxin(s) in the water. It is best to stay out of water experiencing a bloom and wait for the bloom to dissipate on its own.

Landowners and interested citizens can help minimize the problems associated with algal blooms by working together with conservation partners in their watershed to reduce the amount of nutrients that reach nearby lakes, streams, and ponds. You can help reduce nutrient concentrations by promoting the following practices in your community:

- Use lawn fertilizers only where truly needed
- Prevent yard debris (e.g., leaves, grass clippings, etc.) from washing into storm drains
- Support local ordinances that require silt curtains for residential and commercial construction sites
- Plant and maintain vegetative buffer strips along shorelines of lakes, ponds, and streams. Keep in mind that native plants are much more effective at filtering runoff than the grass species typically found on residential lawns.

Blue-green algae can be toxic to humans and animals. If you think you are experiencing symptoms related to exposure to blue-green algae (e.g., stomach cramps, diarrhea, vomiting, headache, fever, muscle weakness, difficulty breathing), contact your doctor or the Poison Information Hotline at 800-222-1222.

If your pet displays symptoms such as seizures, vomiting, or diarrhea after contact with surface water, contact your veterinarian right away.

To report a case with potential health effects caused by blue-green algae, contact the Bureau of Environmental and Occupational Health at 608-266-1120. Or, if you are (or your local community is) interested in collecting samples for analysis, please contact the Wisconsin State Laboratory of Hygiene at 800-442-4618.

For more information on blue-green algae, visit **dnr.wi.gov/lakes/bluegreenalgae**.